

Crop Selection for IFDM Systems

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Chapter 5. Crop Selection for IFDM Systems

A. Introduction

Many salt-tolerant crops, forages and halophytes play important roles in IFDM systems. This chapter provides a summary of potential candidates based on the literature and the most recent research findings from field and greenhouse studies in California. This chapter is less detailed than the crop selection chapter in the IFDM Landowner's Manual. If more detailed recommendations are needed, refer to the Landowner's Manual.

The cropping pattern selected by the operator will be the one that provides the most economic benefit. Therefore, this chapter focuses on those crops with the highest economic value.

As the production areas are defined, the soil type and quality, and the potential irrigation water quality will guide the plant selection. For the freshwater-irrigated acreage, the crops being used will be typical agronomic crops ranging in salt tolerance from sensitive to tolerant. In the reuse areas, forages and salt-tolerant agronomic or industrial crops, such as canola or cotton, can be grown. If needed, there may be a last reuse area where halophytes (highly salt-tolerant, undomesticated plants) will be grown. The following section provides guidance on plant selection for IFDM:

B. Choosing the Appropriate Plants

Candidate plants vary in salt tolerance, plant vigor, desirability and compatibility with local farming operations. Some crops will be more appropriate in a particular area while others may be more appropriate in other areas.

The desired characteristics of plants to be irrigated with saline drainage water include:

- Salinity and boron tolerance
- High production potential (biomass/area)
- High water use (ET)
- Tolerance to frequent flooding – *if using flood irrigation*
- Marketability of harvested biomass
- Perennials or long season annuals (preferred)
- Frost tolerance
- Non-invasive plant
- Plant is NOT a host for insect vectors of plant viruses

In the process of choosing plants, keep in mind the areas of the IFDM system where they will be grown, as well as the soil conditions, and the purpose of that area. In the first production area – an area irrigated only with fresh canal water – there is an opportunity for salt-sensitive plants to be grown, resulting in higher potential profit. In the reuse areas where drainage water is applied to the plants, criteria such as salt and boron tolerance are paramount.

Prior to any plant selection, representative water samples should be taken from a groundwater monitoring well or a drainage sump that represents the quality of the water source that will be used for irrigation. These samples should be sent to a reputable commercial laboratory for analysis of EC, B, Na, Ca, Mg, Cl, SO₄ and SAR. Results of the analyses are the initial guide for plant selection. Soil type, and the availability of non-saline canal water for irrigation, blending, or reclamation leaching are also important considerations.

Table 5-1. A comparison of salinity tolerance[†] for various plants in an IFDM system.

Plants	Irrigation water salinity (EC _w) (fresh, blended, or drainage)
Salt-sensitive vegetables	below 2 dS/m ^{††}
Salt-tolerant vegetables & flowers	below 4.5 dS/m ^{††}
Salt-tolerant field crops (<i>cotton, canola, barley, sugarbeet</i>)	below 7 dS/m ^{††}
Salt-tolerant forages	8-14 dS/m ^{†††}
Halophytes	15 dS/m and above
Salt-tolerant trees	5-10 dS/m

[†] Refer to Maas Hoffman tables (Appendix pages A-31 to A-40) for salinity tolerance rankings.

^{††} Irrigation waters above these threshold values may be used in certain cases, but optimal water and soil management is needed and some yield reduction is likely. Likewise, yield reductions can also occur with waters below the threshold values.

^{†††} Jose Tall Wheatgrass, Paspalum, and Bermuda grass may tolerate short- term irrigation with more saline water.

C. Salt and Boron Tolerance of Traditional Crops

Salinity and boron tolerance are the main factors influencing plant selection in IFDM systems. The Maas-Hoffman tables (Maas & Grattan, 1999) provide salinity tolerance rankings for many traditional fiber, grain, forage, vegetable, horticultural and woody crops. Halophytes are not listed, and only limited information is available for salt-tolerant forages. These tables may be found at the USDA George E. Brown Salinity lab website (<http://www.ussl.ars.usda.gov/>) or in Appendix (pages A-31 to A-40).

IFDM systems utilize saline water. Therefore, the starting point for plant selection is actually the applied water salinity (drainage or drainage blend), rather than the soil salinity. The soil salinity (EC_e) resulting from irrigation with water of a given salinity (EC_w) is difficult to predict because of the influences of soil texture, ET, drainage, duration of saline irrigation, and leaching fraction. A reasonable estimate provided by Ayers and Westcot (1985) is: (EC_e) = 1.5 x irrigation water salinity (EC_w); assuming a continuous leaching fraction of 15-20%. With increasing years of drainage water irrigation, information on the soil salinities tolerated by candidate plants becomes more critical.

Cotton, barley and canola are among the most salt-tolerant field crops. For example, if the soil salinity threshold for cotton is 7.7 dS/m EC_e, the estimated limit for irrigation water salinity that could be applied to cotton over the long-term without yield loss would be 5.1 dS/m. Canola is even more salt-tolerant than cotton, having a soil salinity threshold of 11.0 dS/m EC_e. Canola shows promise both as a selenium accumulator and as a biodiesel crop (G. Banuelos, USDA-WMRL, Parlier, CA, personal communication).

Asparagus, artichokes, red beets, and zucchini squash are among the most salt-tolerant vegetables. However, most drainage waters should be blended with fresh water to keep the salinity of the irrigation water low enough to achieve reasonable production for these vegetables.

Maas and Hoffman also compiled boron tolerance tables (Maas & Grattan, 1999) that list threshold values for numerous agronomic crops based on the boron concentrations in the “soil water.” Some salt-tolerant crops, for example cotton, sugarbeets, asparagus and red beet, are also tolerant (“T”) or moderately tolerant (“MT”) to boron. Alfalfa is boron-tolerant and although it is listed as moderately sensitive (“MS”) to salinity, new varieties with somewhat higher salt tolerance are now available. Tomato and garlic also are boron tolerant; but they are moderately sensitive and sensitive (“S”), respectively, to salinity. These boron tolerance tables do not have listings for salt-tolerant forages or halophytes.

With soil boron concentrations of 4-8 ppm (mg/L) in the saturated paste extract and/or drainage waters of similar concentration, only boron-tolerant agronomic plants should be planted. For drainage waters of 10-15 ppm boron, blending could be utilized, as is done at AndrewsAg in southern Kern Co. Boron toxicity was not observed in trials in the SJV, in which annual crops were irrigated with saline-sodic drainage water containing 7 to 10 ppm (mg/L) boron. These included cotton, melon, sugar beet, tomato and wheat (data

summarized in Grattan & Oster, 2003). However, for permanent crops such as tree fruits and nuts, the potential for boron toxicity remains as a major limitation on their use in IFDM systems, even if they should have adequate salt tolerance.

D. Salt -Tolerant Forages

A number of salt-tolerant grass and leguminous forages have been evaluated in experiments conducted in both the greenhouse and field. Table 5-2 below qualitatively ranks these candidate forages for characteristics that are desirable for IFDM. The maximum EC_w values are based on good drainage and do not reflect maximum yields, but rather, they refer to the suggested maximum that can be used to achieve reasonable production under good management conditions. Ideally, a forage production system should include both warm- and cool-season types, and legumes along with the grasses. Except for the trefoils, it is generally recommended that species be planted separately, rather than inter-planting. The challenge is to manage the stand, i.e. cutting frequency and height, to maximize both the productivity (biomass accumulation) and the forage quality. Generally, as biomass accumulates (more time is allowed between cuttings), forage quality decreases. A summary table showing data on forage performance at Red Rock Ranch can be found in Appendix 5 (page A-41).

Research thus far suggests that, in general, salinity does not reduce forage quality (Robinson, et al., 2004), but it can increase ash and nitrate, both of which are undesirable. Also, more frequent monitoring of elemental composition is required for drainage water-irrigated forages because if excessive concentrations of selenium, sulfur, molybdenum or nitrate should occur, they could cause nutritional problems for the animals (Grattan et al., 2004). In the case of selenium, extremely high concentrations in the forage could be advantageous should the material be processed into a selenium supplement. Animals on the east side San Joaquin Valley and in other production areas are commonly given selenium supplements at considerable cost to the producer.

Table 5-2 compares candidate forages for IFDM using the desired characteristics. The forage quality rankings are on a relative scale comparing only the forages listed and only under conditions of saline irrigation. The irrigation water salinity (ECw) values listed assume good drainage.

	Recommended ¹ ECw (dS/m)	Forage Quality	Growing Season ²	Length of Growing Season	Suitability for Hay or Grazing ³	Seed or Transplant Availability ⁴	Competitive Ability
Tall grass forages							
'Jose' Tall Wheatgrass	≤ 12	High	Weakly cool	Long	Grazing or hay	Good (seed)	Good
Creeping wildrye var. 'Rio'	≤ 9	Medium low	Weakly cool	Long	Grazing or hay	Fair (seed; plugs better)	V. Good
Tall fescue var. 'Alta'	≤ 8	Medium high	Weakly cool	Medium long	Grazing or hay	Good (seed)	Average to Good
Alkali sacaton, var. 'Solado'	≤ 10	Low	Warm	Medium	Grazing	Fair (seed; plugs better)	Good
Perlagrass	≤ 9	Medium	Cool	Medium	Grazing or hay	Fair (seed; plugs better)	Poor
Puccinellia	≤ 10	High	Strictly cool	Short	Grazing or hay	Fair (seed)	Average
Turfgrass or forage							
Bermuda grass	≤ 10	Medium	Warm	Medium	Grazing or hay	Good (seed)	Average to good
Paspalum	≤ 11	Medium high	Warm	Medium long	Grazing or hay	Good (sod or stolons)	Average to good
Leguminous forages							
Salt-tolerant alfalfas	≤ 7	High	Warm	Long	Hay	Very good (seed)	Average to good
Trefoil – narrow leaf	≤ 8	High	Weakly cool	Short	Grazing or hay	Fair (seed)	Average

¹ With irrigation waters less than 8 dS/m, a crop or forage with lower salt tolerance but higher profit potential, may be the better choice. At the high end of the salinity range, productivity may be significantly reduced. Estimates are based on available scientific data and/or personal communications.

² "Weakly cool": forage grows best in the spring and fall. Does not go dormant in the summer, but growth is greatly reduced.

³ Listings are best current estimates. Response to grazing under saline irrigation has not been thoroughly tested for many of these forages.

⁴ "Good": commercial sources readily available and can supply large amounts. "Fair": commercial sources may not be available, but small amounts can be procured from the USDA Plant Materials Center (PMC) in Lockeford, CA or from special purveyors.

'Jose' Tall wheatgrass (*Thinopyrum ponticum*, formerly *Agropyron elongatum*, var. 'Jose') is considered to be a top candidate because of its demonstrated performance under highly saline conditions at Red Rock Ranch (6.8 to 7.1 MT/ha/yr of DM at a soil salinity of 17-19 dS/m ECe). It has relatively high forage quality, a long growing season, and seed is readily available.

Creeping wildrye, also called Beardless wildrye (*Leymus triticoides* or *Elymus triticoides* var. 'Rio') growing in less saline soil (11 to 13 dS/m ECe) at Red Rock Ranch had high biomass production (11.5 to 13.0 MT/ha/yr of DM), but forage quality was lower than for 'Jose' Tall wheatgrass. Selenium accumulation can be very high, e.g. up to 11 ppm (mg/kg DM), in a mature stand irrigated with saline drainage water for five years.

Paspalum (*Paspalum vaginatum* vars. 'Polo', 'PI 299042', and 'Sealsle 1') is also a top contender. It has good productivity and forage quality under saline irrigation and being a warm-season grass, it complements the production of cool-season grasses, such as tall wheatgrass and creeping wild rye. Paspalum has not been extensively tested in the field under irrigation with drainage water, but it was a top performer in sand tank studies where synthetic drainage water was applied (Robinson et al., 2004). Paspalum is now established at Red Rock Ranch and at the SJRIP operated by Panoche Drainage District.

Bermudagrass (*Cynodon dactylum*, vars. 'Common', 'Giant' and 'Tifton') has performed well in a beef cattle grazing study at Westlake Farms (Kaffka et al., 2004) where it is growing under irrigation with saline drainage water and in soils having salinities of 13 dS/m ECe in the top 12 inches. Forage quality was considered acceptable-to-good for beef cattle. The animals had good weight gains at a stocking rate of 1.5 steers/acre and with copper supplementation to overcome a molybdenum-induced copper deficiency.

E. Halophytes

Halophytes are largely undomesticated plants that are native to saline coastal marshes or inland salt flats. They are truly salt-requiring. Some halophytes can be irrigated with water as saline as seawater. Halophytes are suitable for irrigation with highly saline water (≥ 15 dS/m; 12,000 ppm TDS) and/or for highly saline soils ($\text{ECe} \geq 20$ dS/m; 16,000 ppm TDS). *Salicornia* and *Allenrolfea* are the most salt-tolerant, thriving in soils of 50-60 dS/m ECe in the top 12 inches. All of the halophytes listed are warm season plants.

At present, these halophytes have limited economic value. But even if no revenue is generated from their cultivation, the value of these plants in an IFDM system is their suitability for irrigation with concentrated drainage water, thereby allowing additional volume reduction prior to the final discharge into a solar evaporation system. Profit is instead gained from the freshwater-irrigated area of the IFDM in the form of improved yields and expanded crop choices resulting from the soil improvement provided by subsurface drainage.

A table of potential halophytes is provided based on desirable characteristics (Table 5-3). Salt and boron tolerance are not included because halophytes are highly tolerant to both.

Table 5-3 compares candidate halophytes based on desirable characteristics for IFDM.

	Suitable EC _w ¹ (dS/m)	Ease of Establishment ²	Maintenance ³	Competitive ability	Availability of seeds or transplants ⁴	Water use (ET)	Economic potential	Selenium uptake	Comments
Annuals									
<i>Salicornia Bigelovii</i>	≥15	More difficult*	Medium	Fair	Poor (proprietary seed)	High	Medium	V. High	* not well-adapted to hard surface crust, best sown onto wet soils in late fall/winter
Perennials									
Saltgrass	≥15	Average (one year)*	None*	Very good	Good (rhizomes or native stands or commercial sources)	Lower	Low	Medium	* new shoots must form on rhizome. Plugs from seed establish faster
Allenrolfea	≥15	Average (one year)*	Low	Good	Fair (sprigs from native stands)	No data	V. Low	High	*new shoots form from sprigs and/or from fallen seed.
Atriplex spp.	≥15	Average	Medium*	Very good	Good (seed; or better container- grown plants from seed or cuttings from native stands)	Medium	Low	Low	* shrubs get very large, best to cut every year or two, but not below 12"
Cordgrass	≥15	Average	Low*	Good	Good (clumps from native sources or plugs from commercial seed)	No data	Low	Medium	* Cutting not required, but may increase ET.

¹ EC_w = electrical conductivity of the irrigation water in dS/m

² Establishment details can be found in Appendix 5 (pages A-44 to A-50). Scale is relative to saline conditions in which the success rate for establishing vegetation is generally lower than for agronomic plantings on non-saline sites.

³ Maintenance scale: "Low" = little care, "Medium" = may require re-seeding (salicornia) or trimming (atriplex), "High" = frequent trimming or re-seeding required.

⁴ Availability: "Good" = commercial sources readily available and can supply large amounts. "Fair" = commercial sources may not be available, but plant material can be collected from native stands or small amounts requested from the USDA Plant Materials Center (PMC) in Lockeford, CA. "Low" = special purveyors and/or formal agreements may be required (salicornia and 'Nypa Forage' (saltgrass)).

Saltgrass, allenrolfea and salicornia are the most promising halophytes thus far. Saltgrass ranks high because once established, maintenance is minimal, and it provides a very dense vegetative cover with an extensive rhizome system that opens up the soil and improves water infiltration and drainage. The dense cover also impedes water evaporation and salt accumulation at the soil surface.

Allenrolfea, or iodine bush, has performed exceptionally well in the IFDM at AndrewsAg. It has competed reasonably well with invading halophytes and selenium accumulation is high. At Red Rock Ranch, Allenrolfea is slowly spreading westward into the most saline areas of the halophyte block.

Salicornia is the halophyte with the greatest potential for economic return and it is a high water user. It also readily accumulates selenium. However, Salicornia establishment can be difficult in fine-textured soils that form a hard surface crust and its utilization is greatly hampered by the lack of available seed. With the exception of collection in the wild, nearly all seed sources remain proprietary and are not commercially available. On the Pacific Coast, the native range of *Salicornia bigelovii*, the annual species, extends only as far north as Santa Barbara; thus local collection is not possible.

Atriplex spp. also grow well under irrigation with saline drainage water and in the challenging soil conditions normally encountered in IFDM halophyte plots. At present, however, Atriplex plantings are not allowed by CDEA due to concerns that it may harbor the sugarbeet yellows virus. Although it has been suggested that Atriplex is no more likely to harbor the virus than would other native vegetation, the restriction is being maintained.

F. Trees

Drainage water is mainly applied to salt-tolerant crops, forages, and halophytes, and only occasionally to trees. Exceptions may be when drainage flows are very high or when drainage water salinities are low (5-8 dS/m). For example, drainage water could be used to irrigate eucalyptus, though ideally with blending and with a subsurface drain line under the tree block. Pistachio trees were irrigated with drainage water with an EC_w of 8 dS/m by micro-sprinklers for more than eight years; but because boron concentrations were very low in these experiments, uncertainty remains about pistachio's tolerance to boron (B. Sanden, UC Cooperative Extension, personal communication).

Trees that are most promising for IFDM systems include: eucalyptus (*Eucalyptus camaldulensis*, 'River Red Gum', clones 4573, 4543, 4544); athel (*Tamarisk aphylla*); and casuarina (*Casuarina cunninghamiana*). Among this group, athel is the most salt-tolerant.

One disadvantage with trees is the long-term investment in establishing orchards and the overall uncertainty of survival over the long-term as the tree is exposed to multiple abiotic stresses (eg salt, boron, water stress, water-logging, and frost). In addition, soil type, climate and salinity of the water will affect the water use (ET) of the trees. ET may be reduced at higher salinities.

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